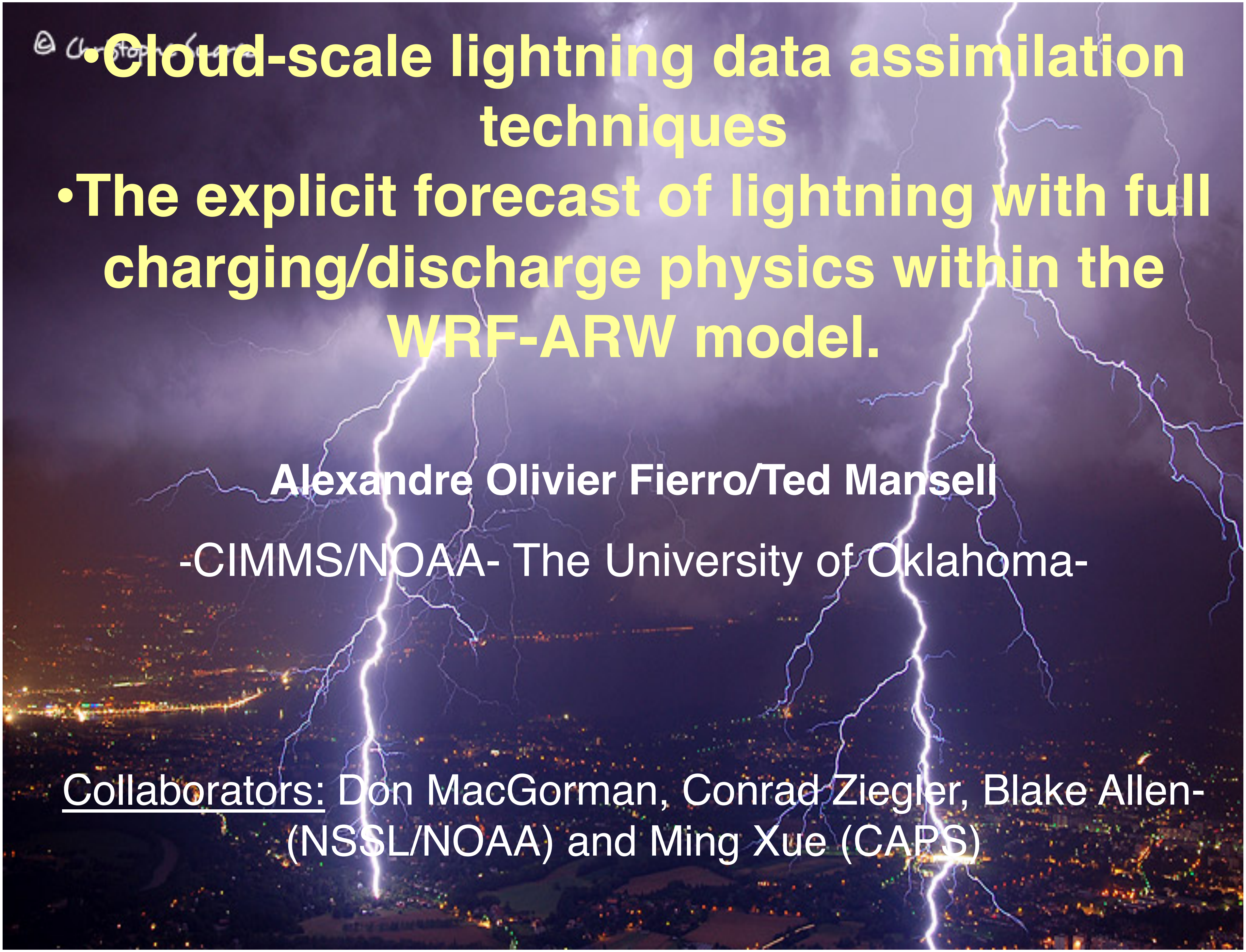


•Cloud-scale lightning data assimilation techniques
•The explicit forecast of lightning with full charging/discharge physics within the WRF-ARW model.

Alexandre Olivier Fierro/Ted Mansell

-CIMMS/NOAA- The University of Oklahoma-

<u>Collaborators:</u> Don MacGorman, Conrad Ziegler, Blake Allen-(NSSL/NOAA) and Ming Xue (CAPS)

Scientific goals:

•Total lightning is correlated to basic storm quantities often diagnosed or predicted in NWP models: graupel/ ice mixing ratio/volume, w, cwc.

•Therefore, *Can total lightning data (IC+CG) be used as a tool within NWP models to provide better initial conditions for convection at cloud resolving/permitting scales (dx ≤ 3/5 km)?*

•Improved Initial Conditions will provide a better physical background at analysis time towards improving short term high impact weather forecasts (~3h). Lightning data can also be used to limit the presence of spurious convection (and cold pools). Key in radar data sparse area.

Methodologies

I. Total lightning data (ENTLN) are being assimilated in real time in the WRF-NSSL operational testbed over CONUS at dx=4 km using a computationally inexpensive smooth analytical function tested at cloud resolving scales (1 km).

II. OSSE experiments (EnKF) within the COMMAS lightning-cloud model are being conducted using operators relating flash rate to storm quantities.

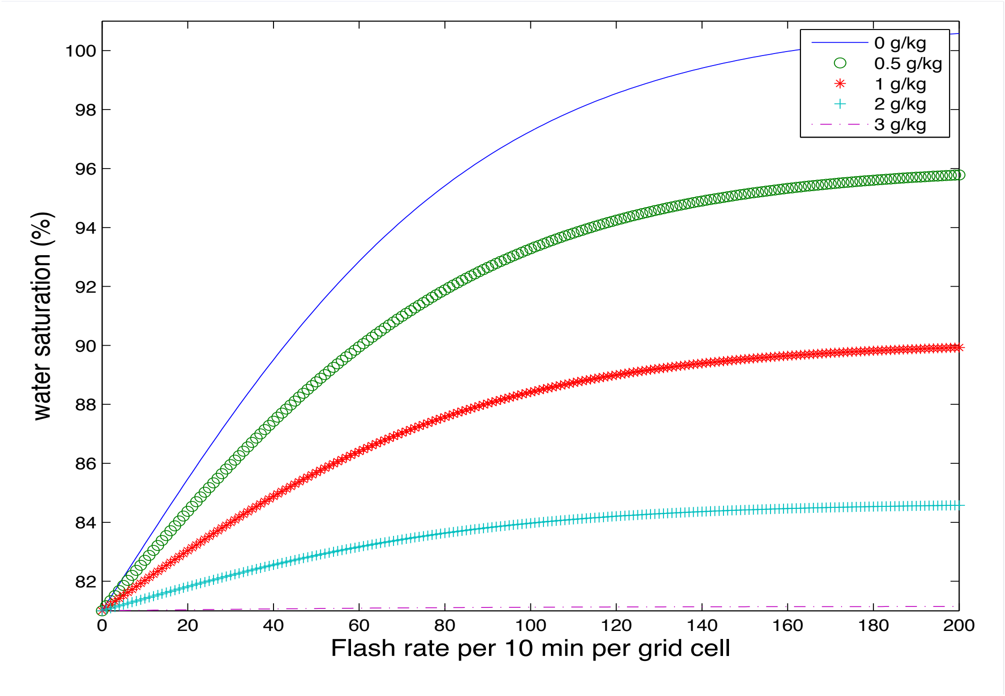
III. As a next step to diagnostic lightning schemes, a full charging/discharge physics lightning model has been successfully implemented into WRF-ARW within the NSSL 2 moment microphysics. Simulated lightning to be used in tandem with GLM obs within EnKF to improve location of storms + simultaneously eliminate spurious convection

I - Lightning nudging function

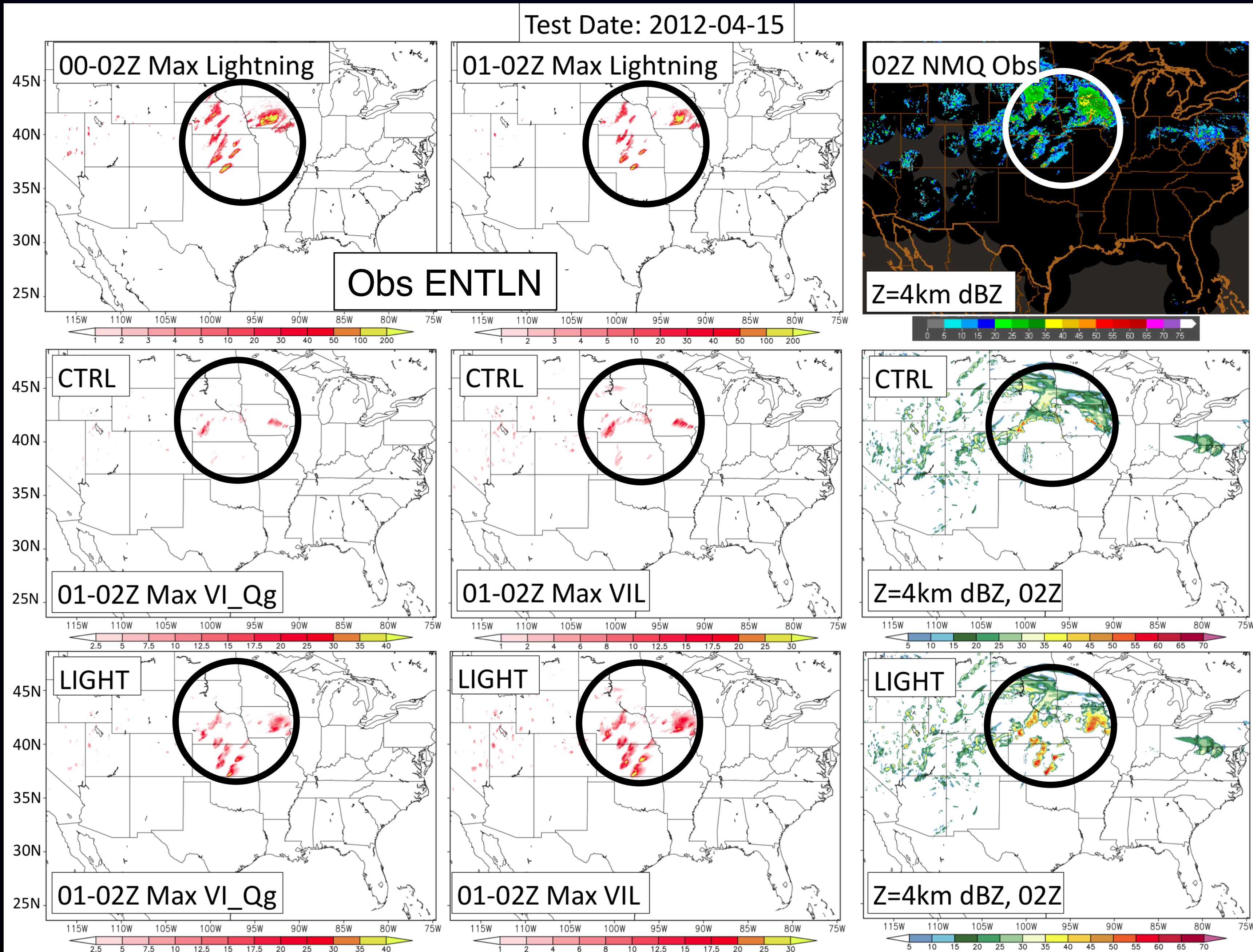
Q_v within the 0°C to -20°C layer was increased as a function of 9-km N_{flash} (X) and simulated Q_g and $Q_{satwater}$. Increasing Q_v at constant T increases θ_v buoyancy and ultimately generate an updraft.

$$Q_v = AQ_{\mathrm{sat}} + BQ_{\mathrm{sat}} \tanh(CX)\left[1 - \tanh(DQ_g^{\alpha})\right]$$

-Only applied whenever simulated RH ≤ A*Qsat and simulated Qg < 3 g/kg.
-A controls minimum RH threshold (here 81%). B and C the slope (how fast to saturate) and D how much Qv is added at a given Qg value.

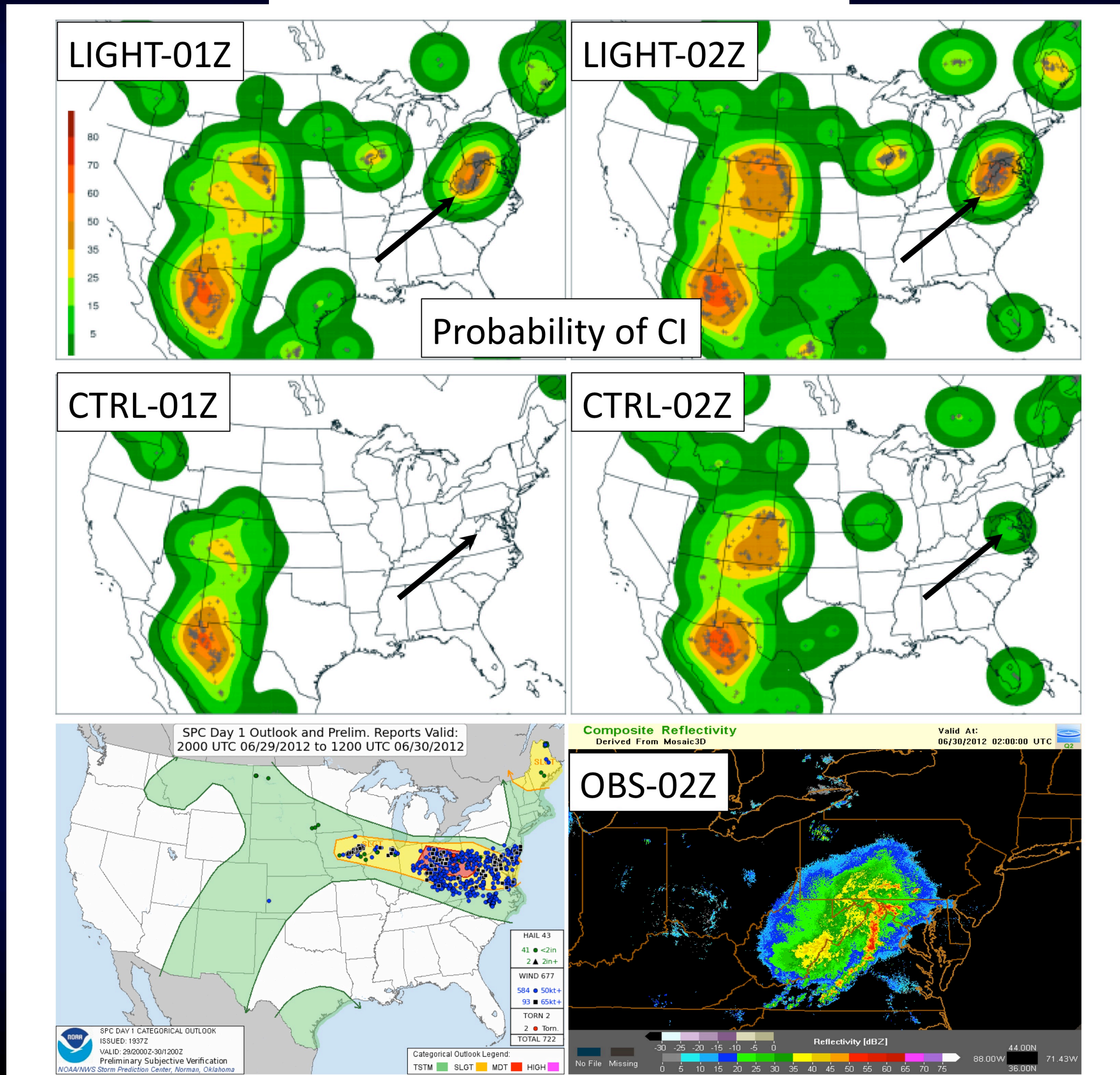


I-Real-time WRF-NSSL 4-km runs over CONUS



I-Real-time WRF-NSSL 4-km runs over CONUS

29-30 June Derecho event



II-EnKF Assimilation of Pseudo-GLM flash rates

Methodology:

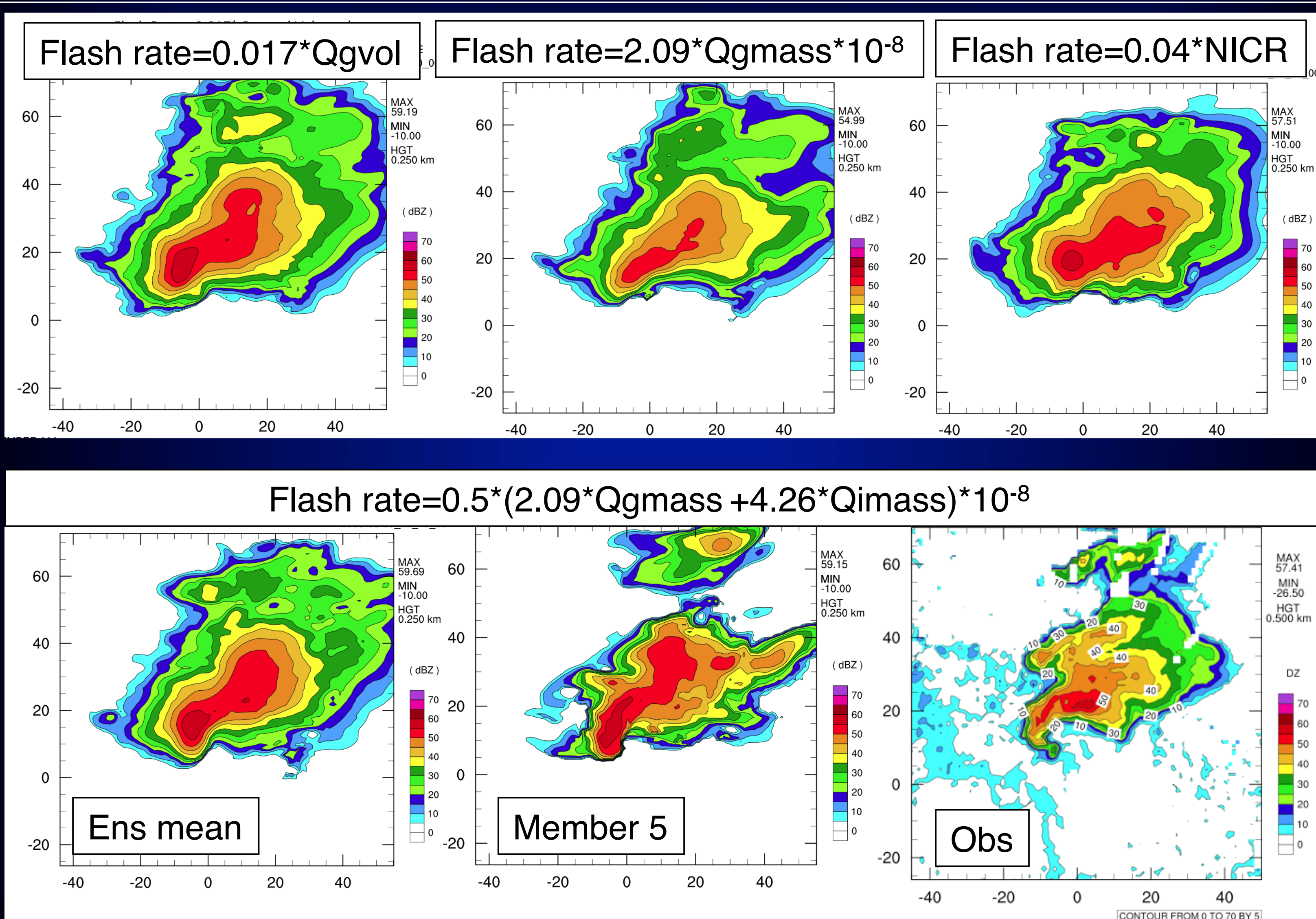
The pseudo-GLM flash rates (derived from OK-LMA on a ~8x6 km grid) were binned in one minute intervals and assimilated using an observation operator that consists of a linear relationship between total flash rate and model quantities known to be well correlated with lightning such as: Graupel mass (Qgmass),

Graupel volume (Qgvol),

Cloud ice mass (Qimass)

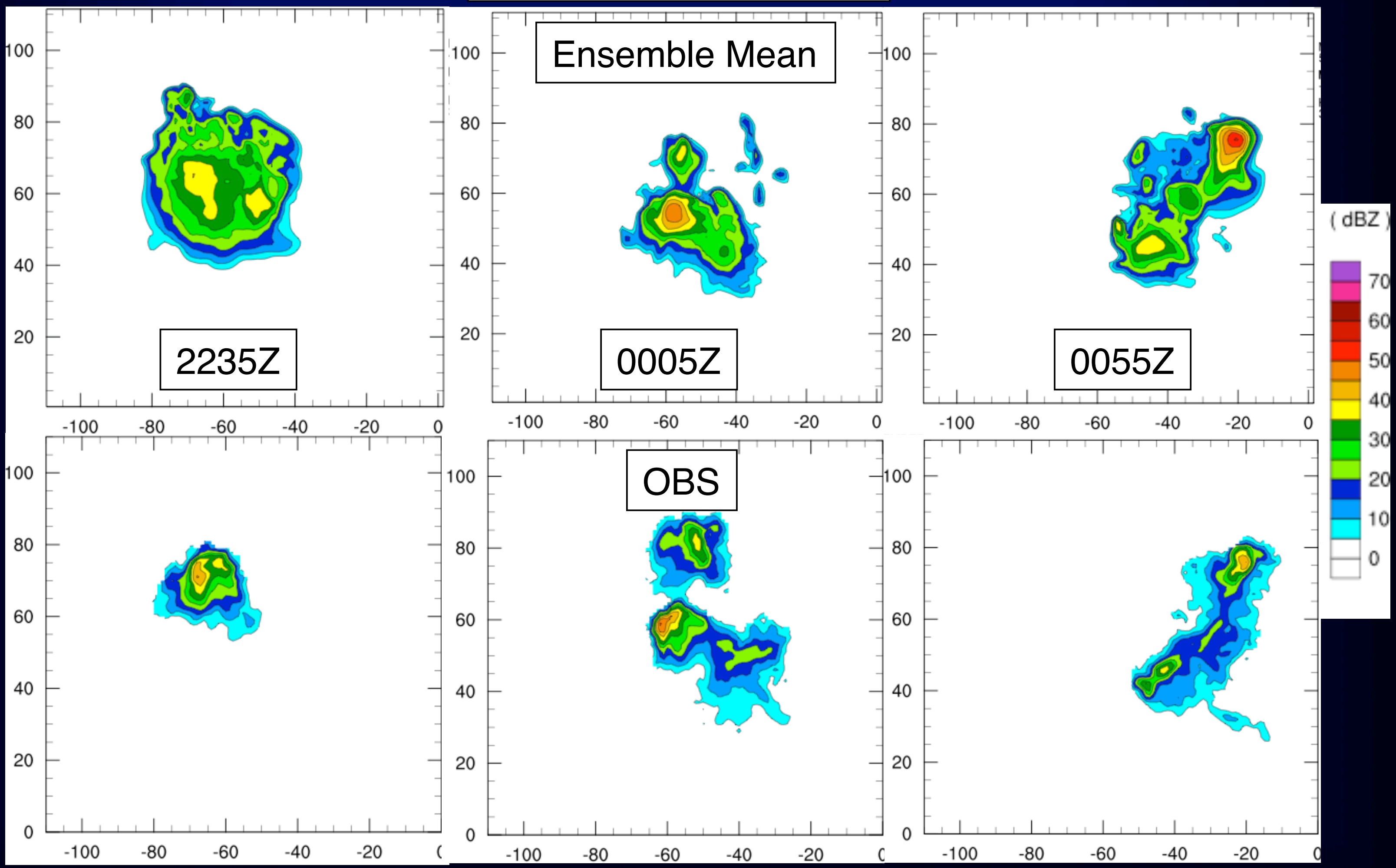
Non inductive charging rate (NICR).

II-EnKF Assimilation of Pseudo-GLM flash rates (8 May 2003 Supercell)



Il-EnKF Assimilation of Pseudo-GLM flash rates (6 June 2000, NE CO pulse storm)

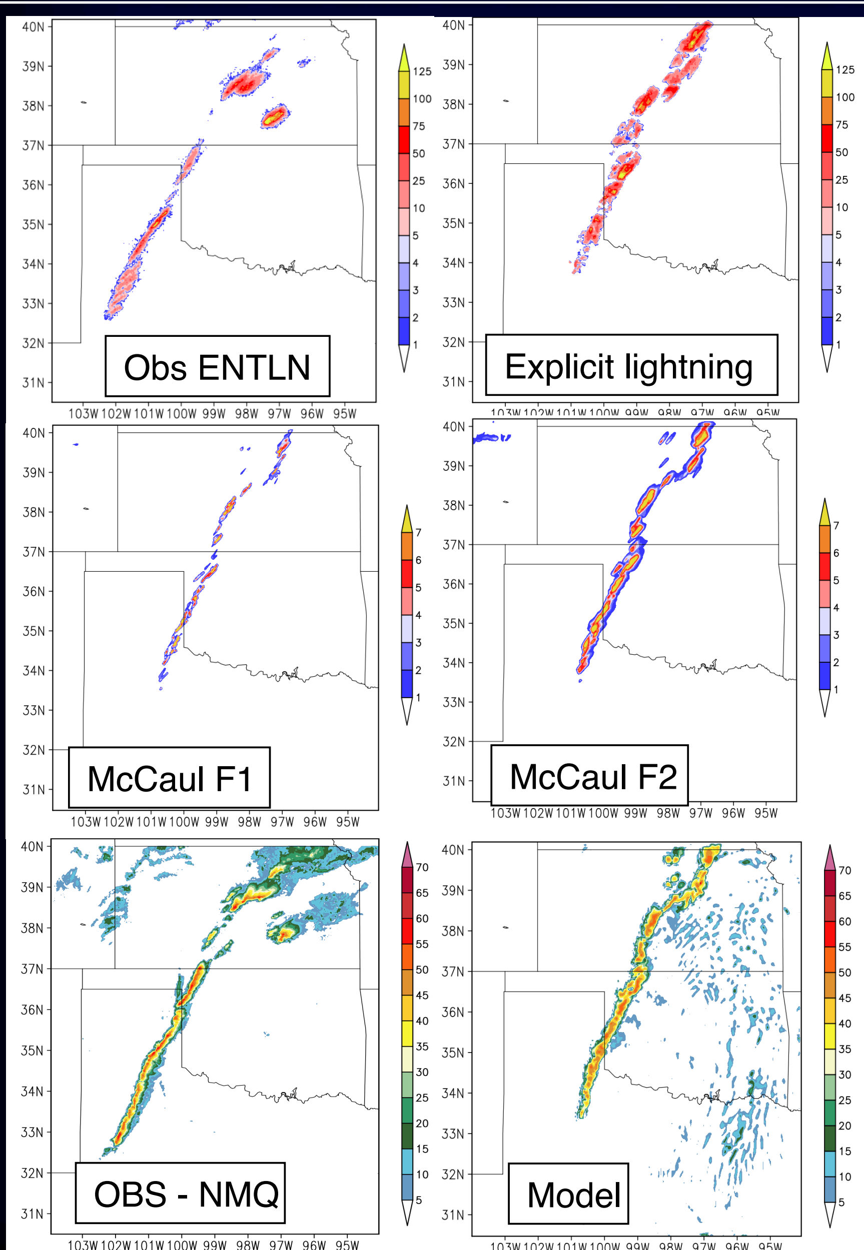
Flash rate=0.017*Qgvol



III-New WRF explicit charging/discharge model

- NSSL 2 moment microphysics (qw, qc, qh, qg, qi and qs).
- 5 non-inductive collisional charging schemes + separation of charge during mass exchange (or phase change)
- Space charge on each hydrometeor species as scalars (sedimentation, diffusion and advection of charge).
- Explicit elliptic solve for the Electric field in 3-D (MPI elliptic/ Poisson solver).
- Polarization/inductive charging.
- 2-D discharge based on Ziegler and McGorman (1994) with removal of charge being a function of hydrometeor surface area and local E.
- Lightning scheme is overall computationally efficient and inexpensive (accounts for ~ 10-13% of CPU increase).

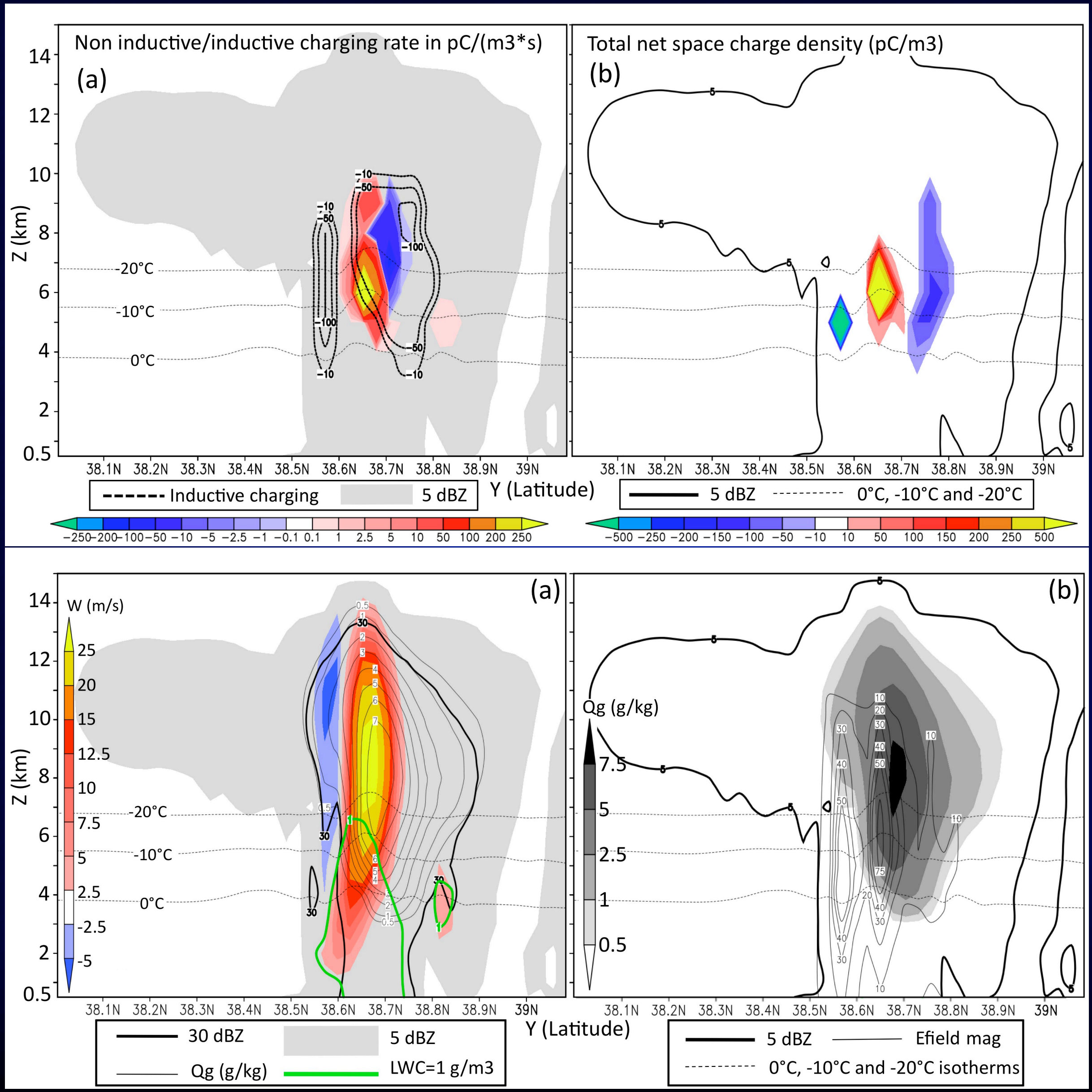
III-15 April 2012 (dx= 3 km) with SP98



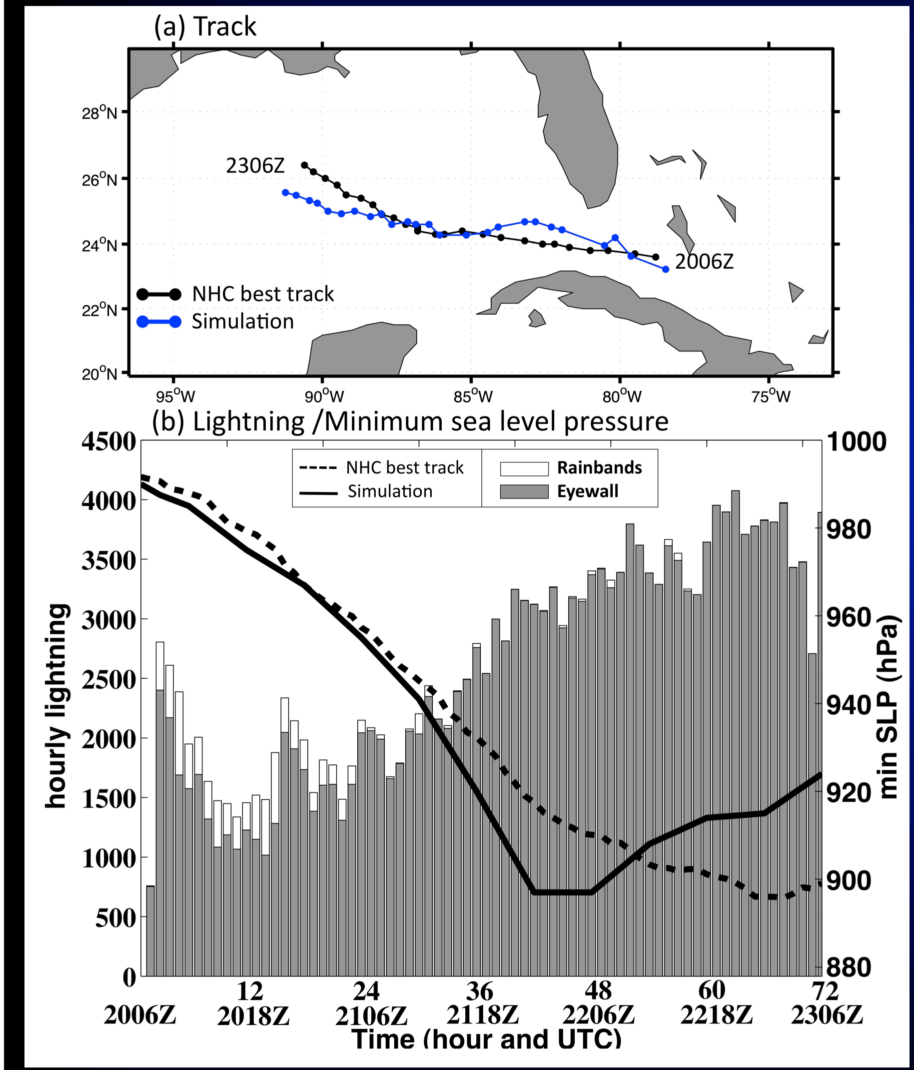
0600Z

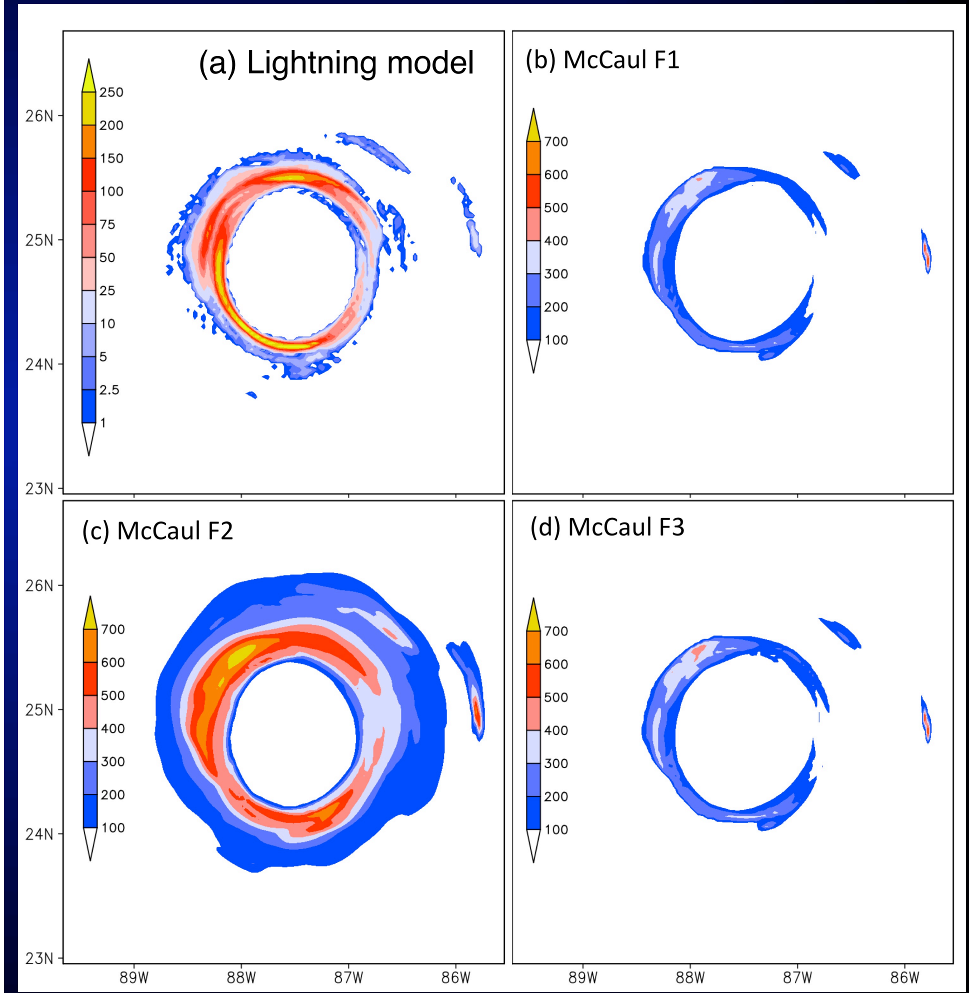
- -WRF model able to capture evolution of this nocturnal squall line
- -Good qualitative agreement between MC diagnostic schemes (F1 to F3) and explicit lightning model

III-15 April 2012 (dx= 3 km) with SP98

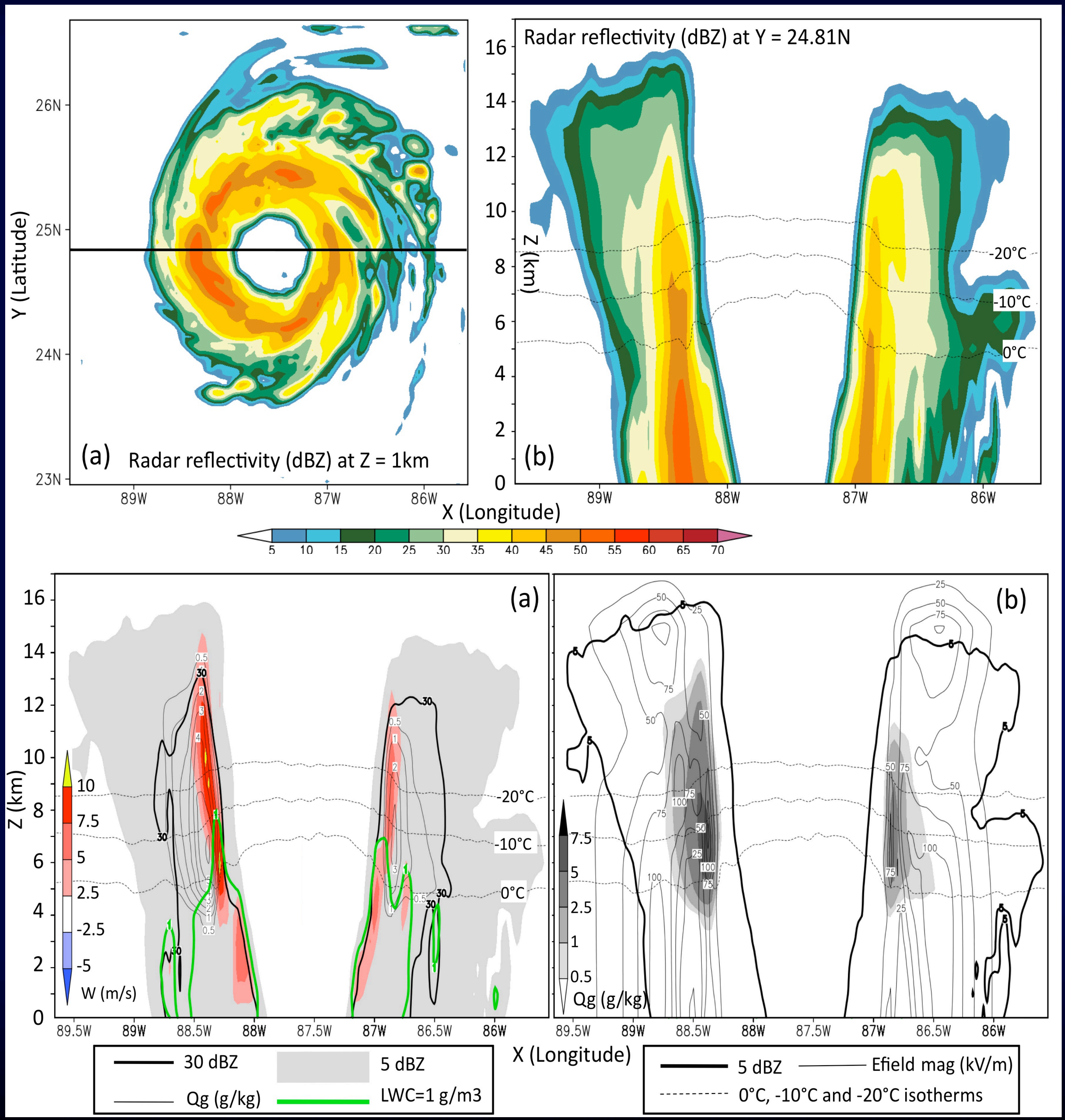


III-Hurricane Rita (dx= 3 km) with SP98

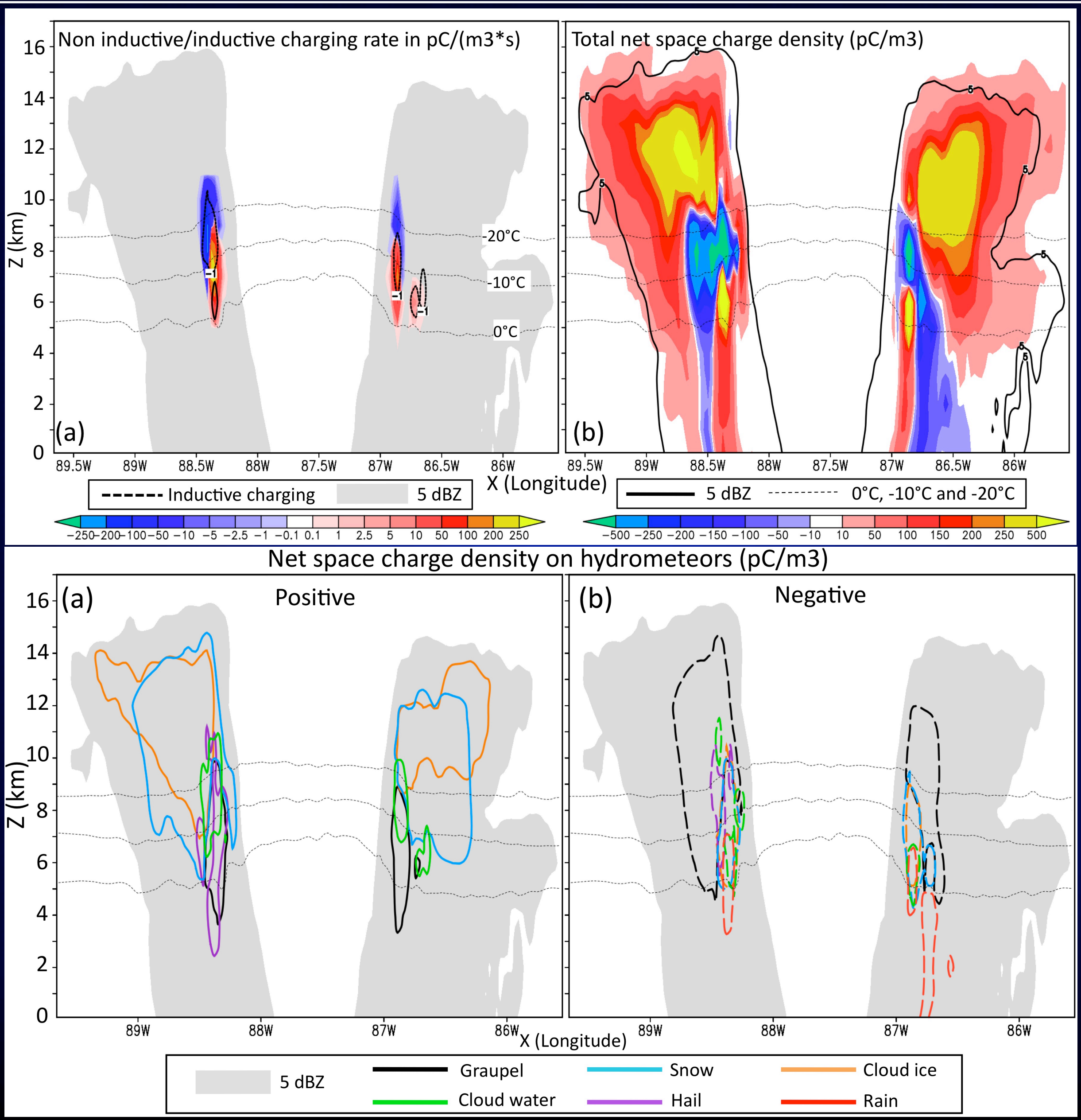




III-Hurricane Rita (dx= 3 km) with SP98



III-Hurricane Rita (dx= 3 km) with SP98

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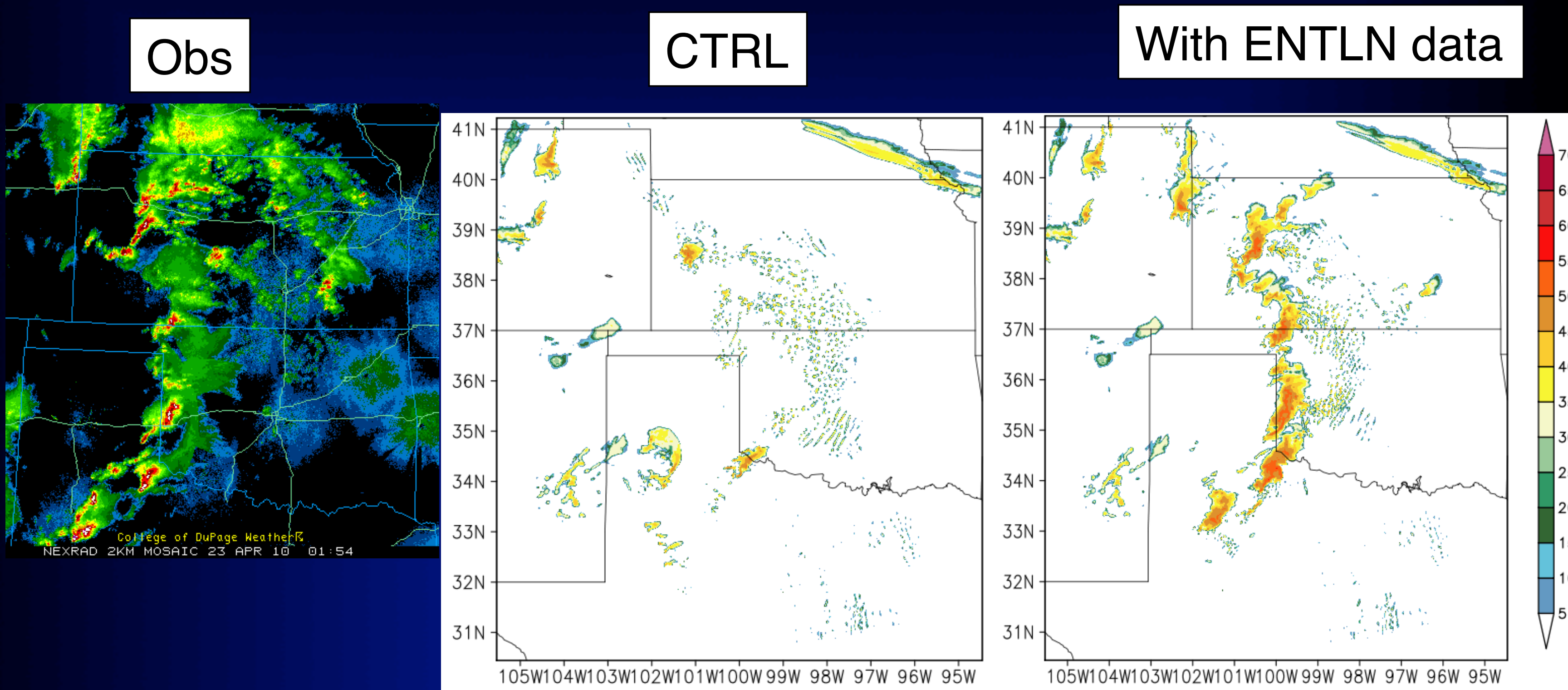
Questions?

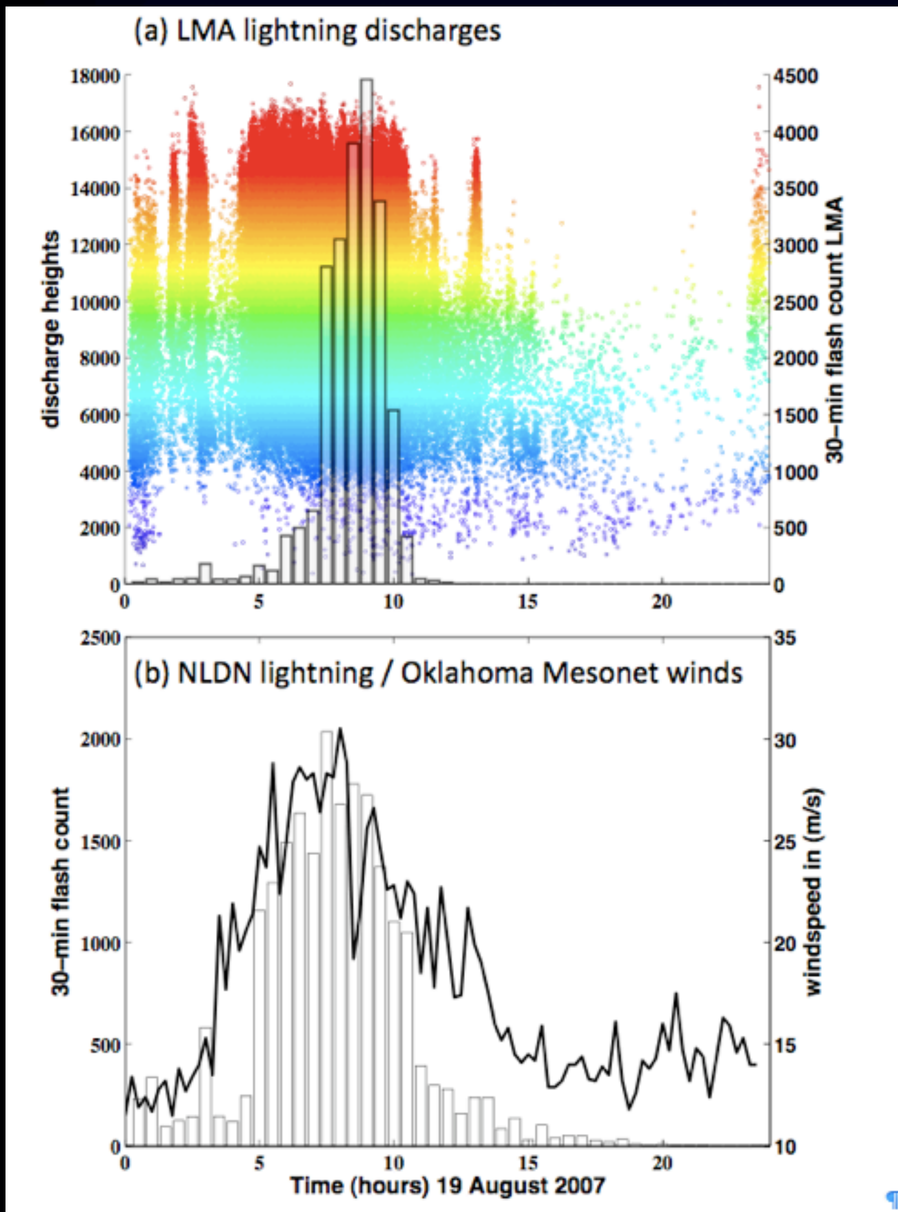
Other case studies: 23 April (1-km): 2 h assimilation



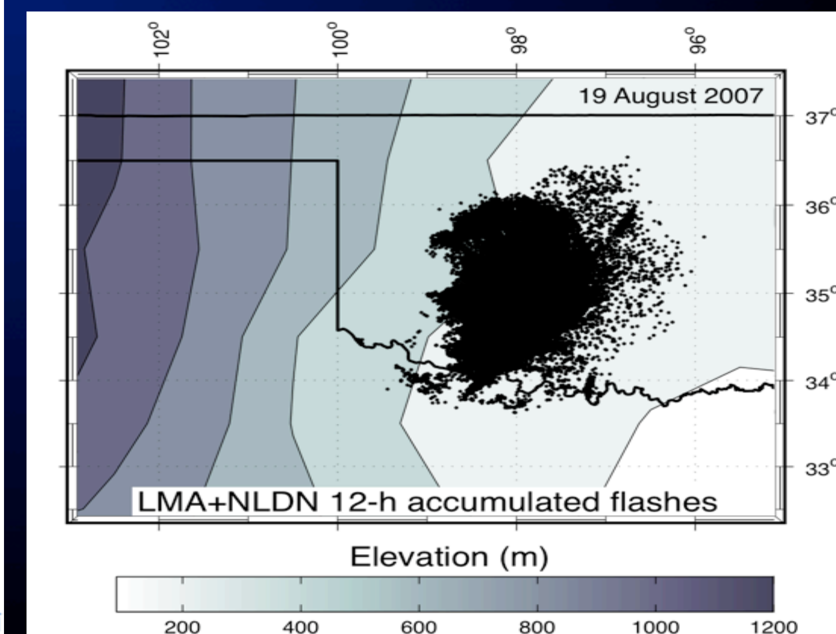
0200Z

As expected, early supercellular activity *at analysis time* is better resolved using lightning (in this case lightning points were supersaturated wrt water in the 0°C to -20°C layer independently of flash rate).

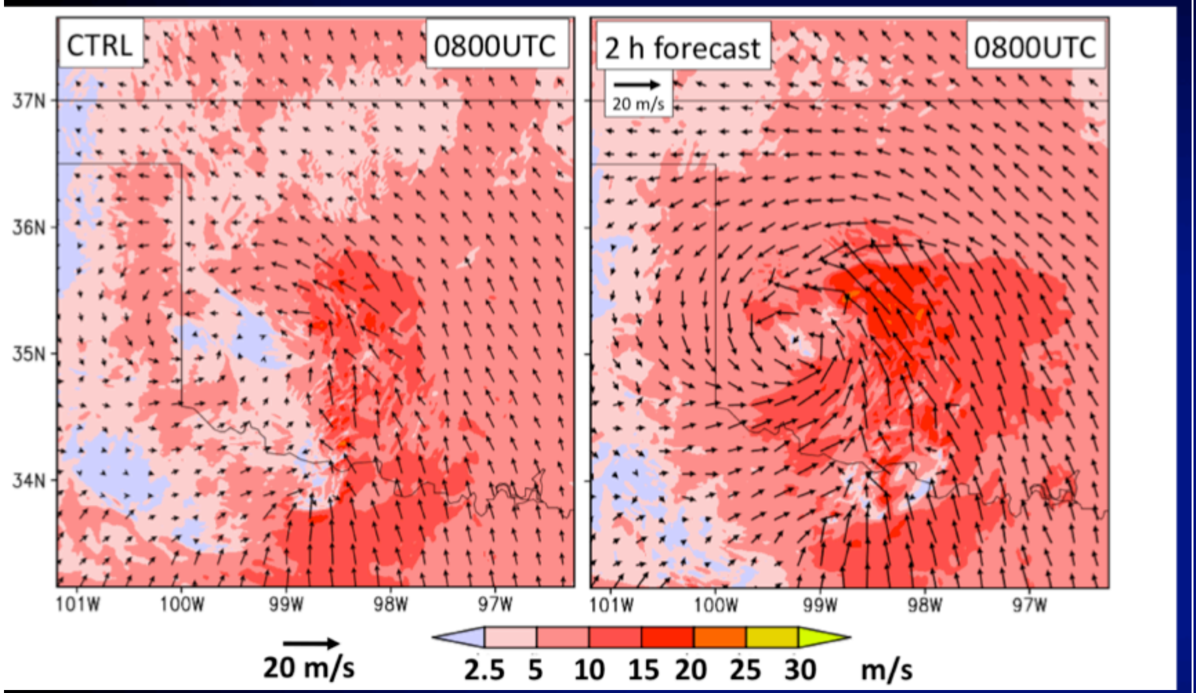
TC Erin: 1) Observations



- •Similar to Rita; TS Erin ‘eyewall’ was lit up with lightning flashes during its intensification period.
- •LMA detected 8 times as many flashes as NLDN-
- •Topology of accumulated 12-h LMA+NLDN flashes starting at 00Z 19 Aug used to ‘control’ microphysics in WRF runs



Tropical Storm Erin



- Assimilating LMA +NLDN lightning data for the first 6 h resulted in a better 2 h (=0800Z) forecast compared to CTRL.
- Note that for this case, the WRF convection had to be severely reduced outside the lightning area for the assimilation to have a notable effect on the vortex intensification

$$if\,(q_x \geq b/\rho_{air})\ then\ q_x = \max(\alpha * q_x, b/\rho_{air})$$

where b is the mixing ratio threshold (0 for run QX0), α=0.2, q_x is the mixing ratio of hydrometeor class x

24 May 2011case

Model setup and WRF lightning nudging:

•Triple nested grid with D01/D02/D03=9/3/1-km and 35 vertical levels. I.e., from GEOS-R (CPS scale) to 'convection-resolving' scales. Focus on the 3-km output (current operational NWP model resolution).

•No feedbacks between grids allowing independent comparisons of the model output on the 3 grids.

•12Z NAM 40-km re-analysis data used as input for IC/BC.

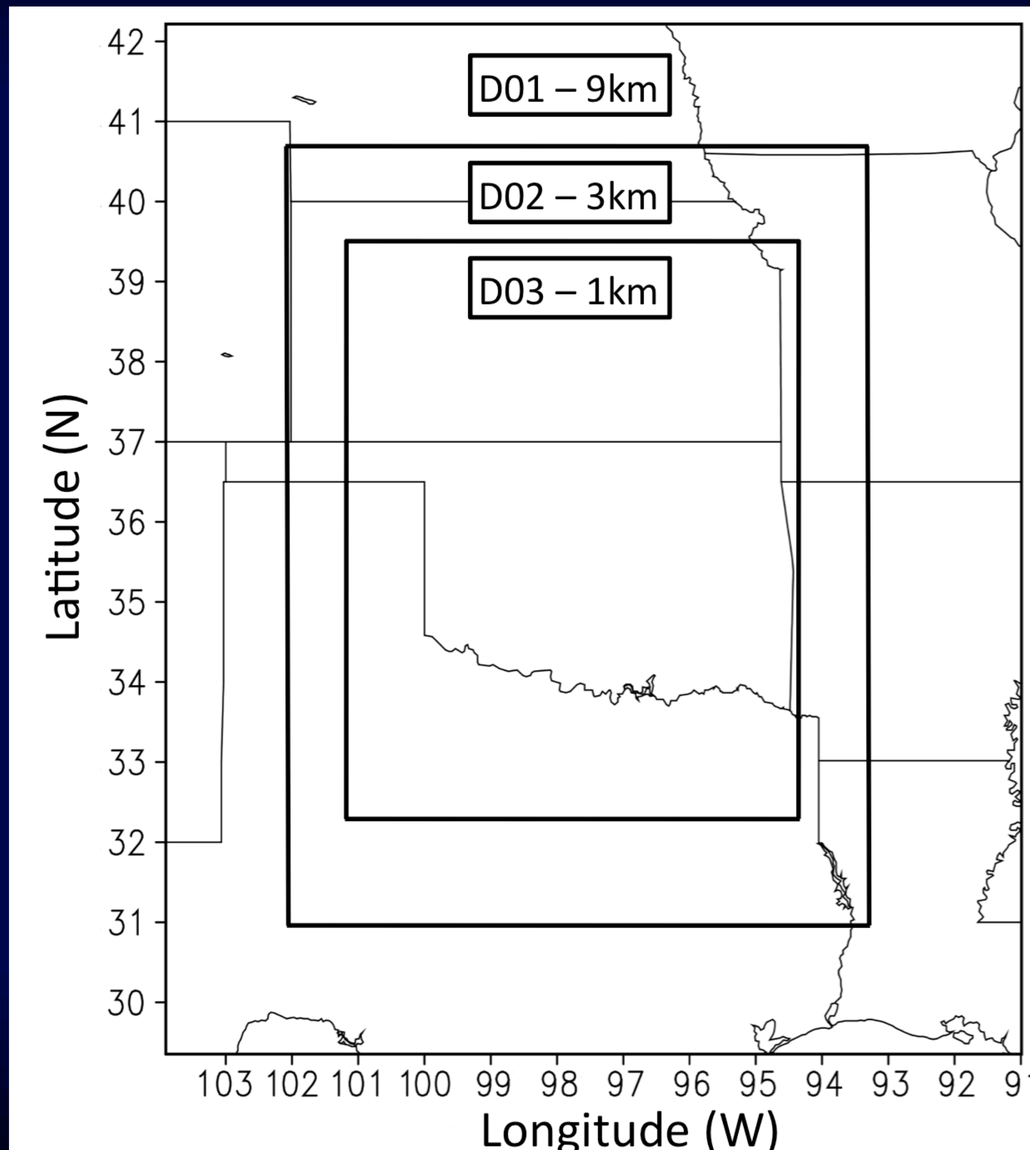
•D01,D02,D03 started at 12, 14, 16Z, respectively.

•Lightning nudged via a smooth continuous function for Q_v within the mixed-phase region (0° to -20°C) as a function of N_{flash} and simulated Q_g (and $Q_{satwater}$). This increases θ_v buoyancy and generates updrafts.

•Lightning nudging conducted within WSM6 microphysics.

•Assimilation of pseudo-GLM 9-km N_{flash} simultaneously on all grids between 1930-2130Z in 10-min bins.

WRF Domain: 24 May

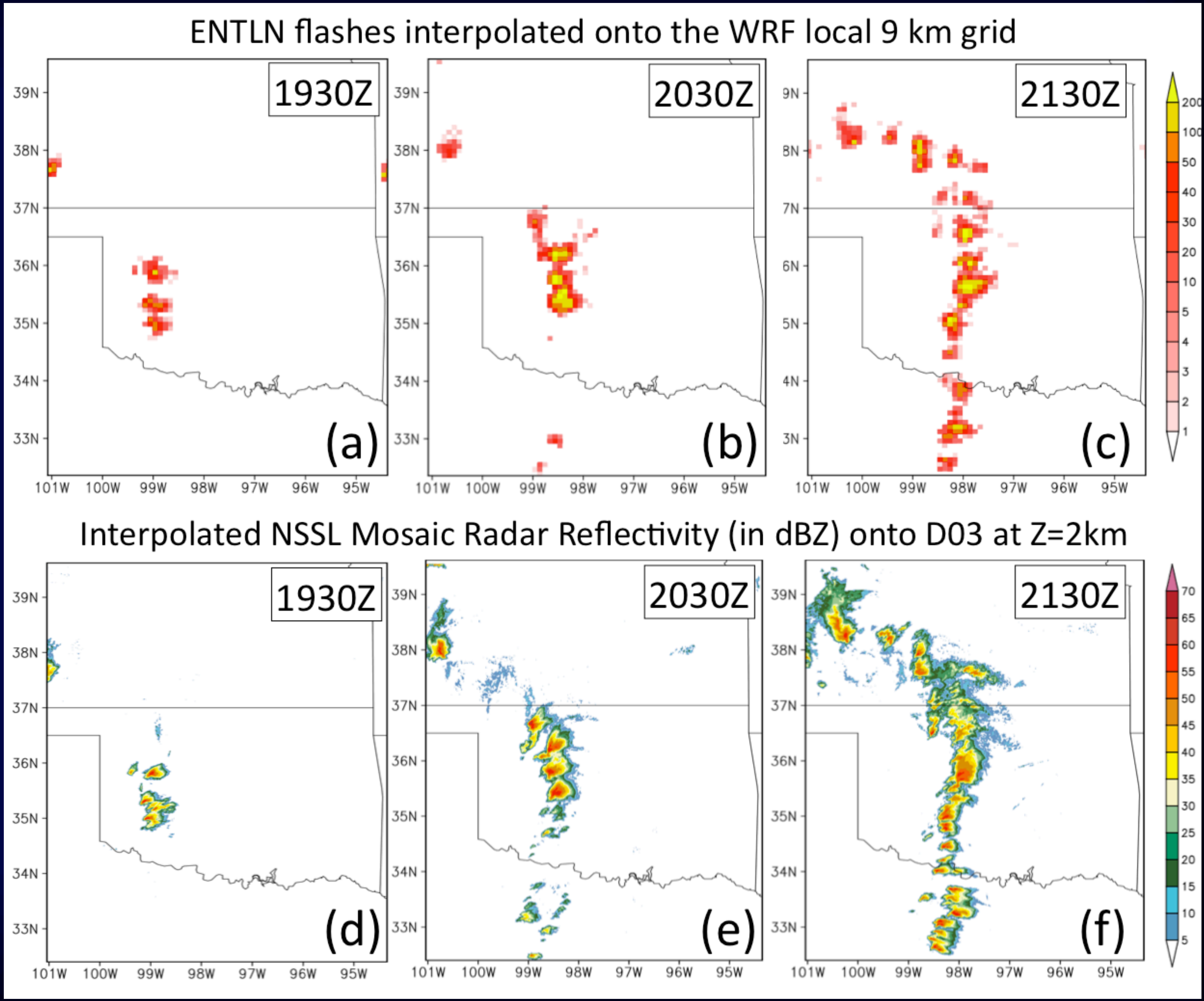


Observations 1930-2130Z

2130Z=analysis time
2230Z=1h forecast

- 9-km interpolated ENTLN flash count
- Same on all 3 grids

OBS-NSSL Mosaic NMQ interpolated onto WRF 1 km grid **D02**



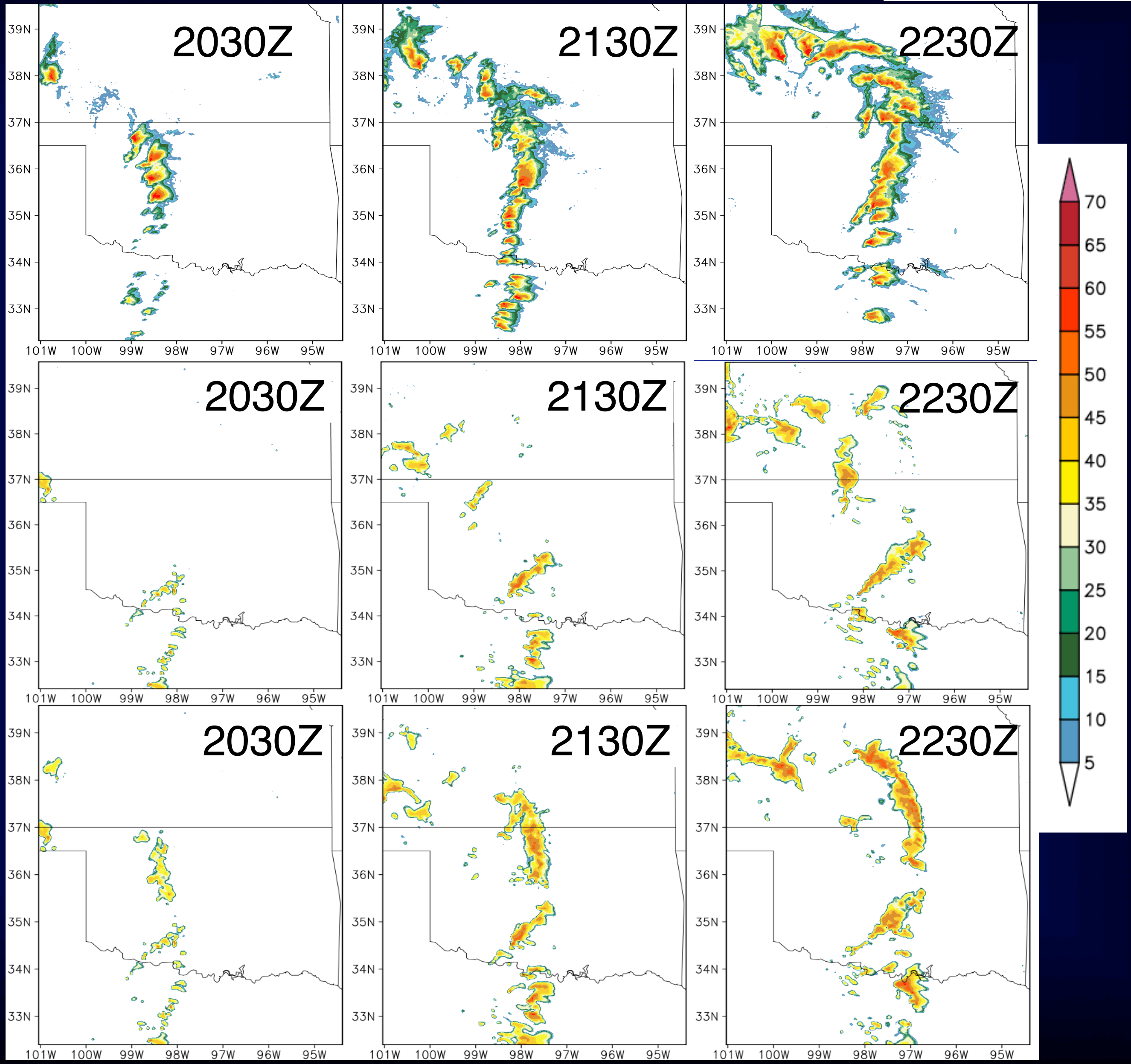
Results (Z=2km) D02

2130Z=analysis time
2230Z=1h forecast

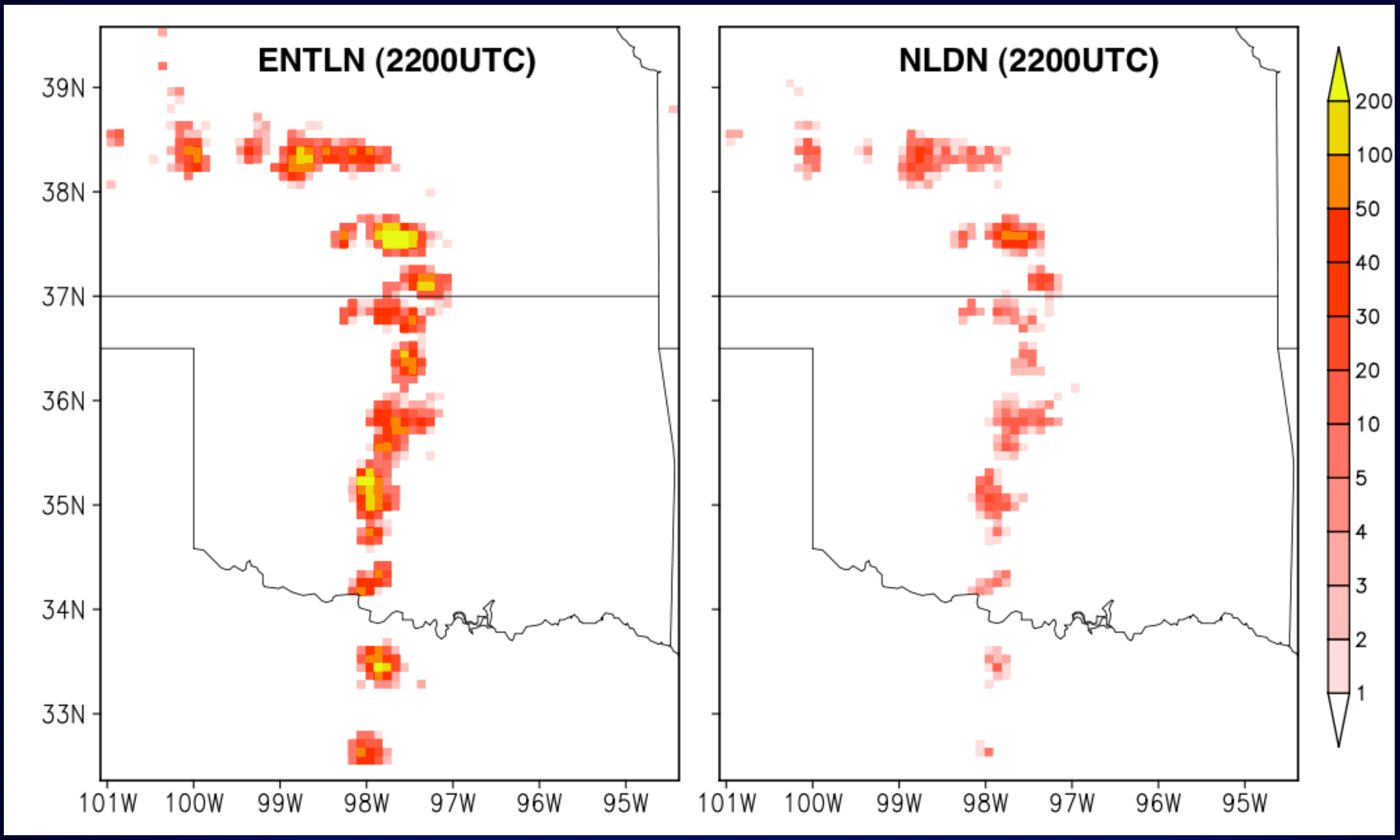
OBS-NSSL MOSAIC Interpolated onto WRF 3-km grid **D02**

CTRL

LIGHT

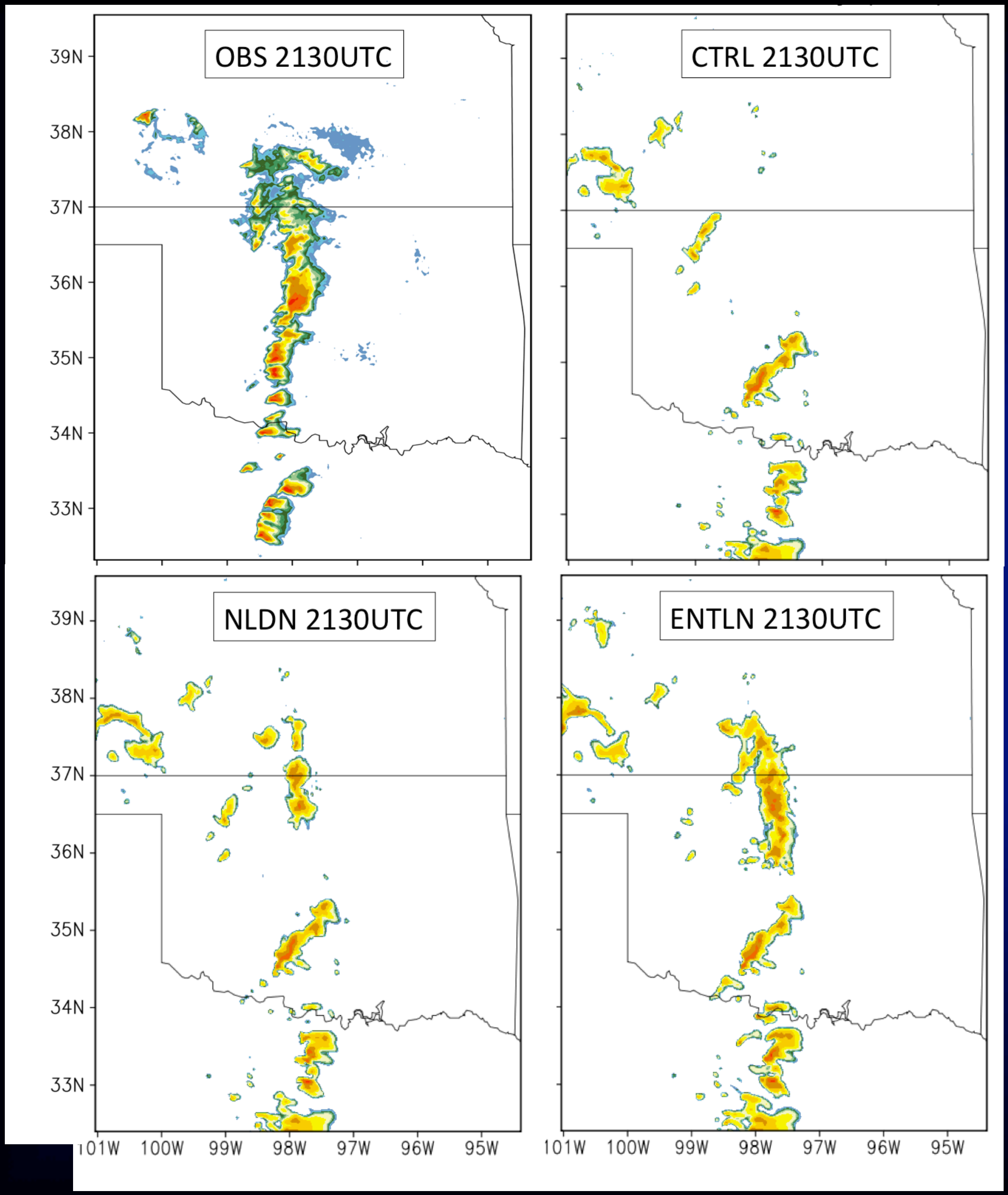


ENTLN (CG+IC) versus NLDN (CG-only)



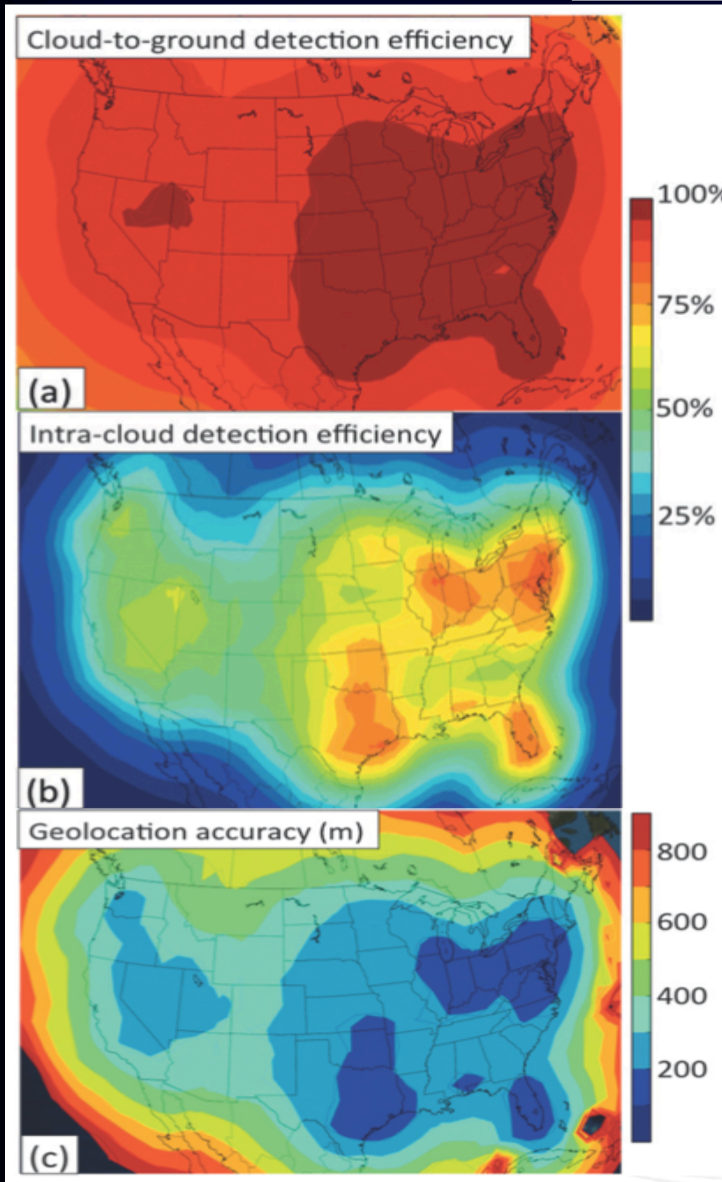
ENTLN/NLDN ≈ (IC+CG)/CG Ratio of 9x9-km 10-min gridded flash counts ranges from 2 to 10. IC+CG also spans a larger area. IC also better correlated with W and hence, timing of the convection.

Assimilation results at analysis time.



As expected from the above preface, the use of total lightning data leads to improved representation of the convection at analysis time than with CG-only.

ENTLN network



Graphics courtesy of Jim Anderson, Stan Heckman and Steve Prinzivalli from EarthNetworks®-Used with Permission.

http://earthnetworks.com/OurNetworks/LightningNetwork.aspx

- Measure broadband electric field, from 1 Hz to 12 MHz.
- Effective proxy for GOES-R total lightning measurements.
- Remarkable detection efficiency for CG return strokes over CONUS (98%) and IC with efficiencies > 70% over OK.
- High network density results in overall small geo-location error generally (< 300 m over OK).